UNCLASSIFIED

AD 403 811

UNCLASSIFIED

$6\,3\,3\,4$

AID Report P-63-53

30 April 1963

SOVIET NUCLEAR RESEARCH REACTORS

OF THE IRT-2000 TYPE

Review of Soviet Literature

AID Work Assignment No. 31

Report 6

Aerospace Information Division
Library of Congress

AID Report P-63-53

30 April 1963

SOVIET NUCLEAR RESEARCH REACTORS

OF THE IRT-2000 TYPE

Review of Soviet Literature

AID Work Assignment No. 31

Report 6

FOREWORD

This is the sixth in a series of reports on Soviet research reactors. The first three reports in this series (AID Reports 62-43, 62-127, and 62-172) were prepared in response to AID Work Assignment No. 16. The fourth report (AID Report 62-197), the fifth report (AID Report P-63-14), and the present report have been prepared in conformance with AID Work Assignment No. 31.

This report presents a detailed description of six Soviet experimental reactors of the IRT-2000 type, viz.: the Moscow IRT-2000 reactor, the Salaspils IRT-2000 reactor, the Tbilisi IRT-2000 reactor, the Tomsk IRT-2000 reactor, the Sverdlovsk IRT-2000 reactor, and the Malyye Dubny IRT-2000 reactor. (The name of each reactor indicates the city in which it is located.)

The presentation includes background information, design features, reactor parameters, and information on experimental facilities and experiments conducted with the reactors, together with illustrations and diagrams. The report is based on Soviet open literature available at the Aerospace Information Division and the Library of Congress. Any further information concerning these reactors will be published in the form of supplements to this report, as soon as it becomes available.

A list of the references cited accompanies the text. Library of Congress call numbers are given at the end of the source entry when the source is available at the Library of Congress.

TABLE OF CONTENTS

THE IRT-2000 REACTORS

BACKGROUND

The Soviet IRT-2000 research reactors are pool-type reactors using water as moderator, reflector, top shielding, and coolant. They operate at a maximum thermal power of 2000 kw and a thermal neutron flux of $3.2 \cdot 10^{13}$ n/cm²·sec. The most important special feature of their basically simple design is the use of an ejector for coolant circulation. Most reactors of this family are equipped with 11 horizontal and a varying number of vertical channels. [1]

The IRT-2000 reactor was originally designed and built at the Atomic Energy Institute, Academy of Sciences USSR, as the IRT-1000 reactor. Startup of the original reactor was accomplished on 23 November 1957 [1] and initial test runs were completed in December 1957 [2]. Results of the initial tests indicated that slight modifications of the design would make it possible to raise the power level from 1000 kw to 2000 kw. Those modifications were accordingly made, and January 1958 saw the successful operation of the reactor at the new power level. It is this modified reactor which is described in the following pages as the Moscow IRT-2000 Reactor. [1]

Since all the IRT-2000 reactors described in this report are similar in design, only one of them, the Moscow IRT-2000 Reactor, will be described in detail. The presentation for the other reactors will be limited to design variants and such other information as is available in the literature.

The Salaspils IRT-2000 Reactor, belonging to the Academy of Sciences Latvian SSR, was put into operation on 9 October 1961 [3]. Construction of this reactor was begun on 26 May 1960 [4]. It went critical on 20 July 1962 [5]. This reactor, which will serve the scientific communities of the Lithuanian SSR and the Estonian SSR [4], is described on pages 20-22 of this report.

The Tbilisi IRT-2000 Reactor, belonging to the Physics Institute, Academy of Sciences Georgian SSR, was put into operation on 21 November 1957 [6]. The reactor is described on pages 23-24 of this report.

The Tomsk IRT-2000 Reactor is still under construction. According to source [7], the reactor was expected to be completed in 1962. No further information concerning this reactor is available at this time.

The Sverdlovsk IRT-2000 Reactor [1], belonging to the Ural Branch, Academy of Sciences USSR, was stated to be under construction in 1958 [8]. No further information concerning this reactor is available at this time.

The Malyye Dubny IRT-2000 Reactor, belonging to the Power Institute, Academy of Sciences Belorussian SSR, was put into operation on 28 April 1962 [9]. This reactor, which will serve all of the Institutes belonging to the Academy of Sciences Belorussian SSR, is described on pages 27-31 of this report.

I. THE MOSCOW IRT-2000 REACTOR

1. General Design

The design and construction of the Moscow IRT-2000 Reactor were carried out by I. P. Frolov, V. M. Zhigachev, P. I. Shavrov, and others. Vertical and horizontal cross sections of the reactor are shown in Figs. 3 and 4 (pages 5 and 6). It is a pool-type reactor, with the reactor core housed in a water-filled aluminum tank surrounded by concrete shielding. The water acts as moderator, reflector, top-shielding, and coolant. A flow diagram of the reactor is given in Fig. 6 (page 9). [1]

2. Construction Details

Fuel Elements and Fuel Assemblies
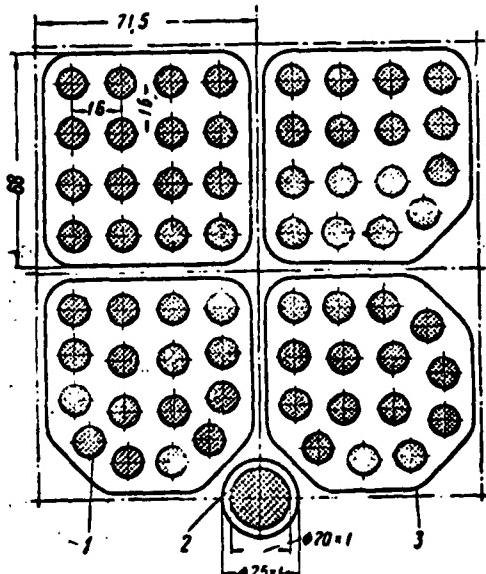
Fig. 1. Arrangement of fuel elements in fuel assembly design variants [1]

1 - fuel element; 2 - control rod; 3 - fuel assembly.

The fuel elements are cylindrical, with a diameter of 10 mm and an active length of 500 mm. Each fuel element consists of a fuel rod made of 10% enriched uranium dioxide diluted with magnesium, encased in an aluminum sheath 1 mm thick. The U^{235} content of each fuel element is 8 g. The ends of the fuel elements are reduced in diameter to 7 mm, to permit their attachment to the spacer grids in the fuel assemblies. Each fuel assembly contains 15 or 16 fuel elements, and is encased in a housing 0.8 mm thick. The fuel assembly housings are provided with windows to facilitate circulation of the coolant and reduce hydraulic resistance. Construction details of fuel elements and fuel assemblies are shown in Figs. 1 and 2. [1]
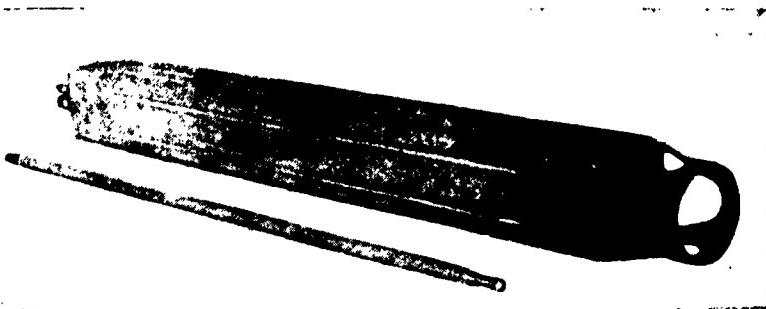
Fig. 2. Fuel element and fuel assembly [1]

Reactor Core

The reactor core is located at the bottom of the aluminum tank under a layer of water 6 m deep (Figs. 3 and 4). A metal plate supports the fuel assemblies; 77% of its area consists of apertures left for the circulation of the coolant. The apertures in the support plate under the peripheral fuel assemblies are provided with baffles for regulating coolant flow according to the rate of heat release in the fuel assemblies. The core is divided into 48 cells. Twenty-six of these are loaded with fuel assemblies at start-up; all 48 are loaded by the end of the run. The empty cells are loaded with graphite rods to secure a uniform neutron flux in the horizontal beam tubes. A horizontal cross section of the core is shown in Fig. 5. [1]

Cooling the Reactor, Thermal Column, and Biological Shielding

A special feature of the primary cooling loop is the use of an ejector to improve coolant circulation (see Fig. 3). Three centrifugal pumps in the primary loop, with a total discharge head of 50 m, pump distilled water through the ejector nozzle at the rate of 175 m³/hr. The ejector draws in additional water from the tank at the rate of 365 m³/hr, giving a total circulation of cooling water through the core of 540 m³/hr.

[Text resumes on p. 8.]

- 4 -
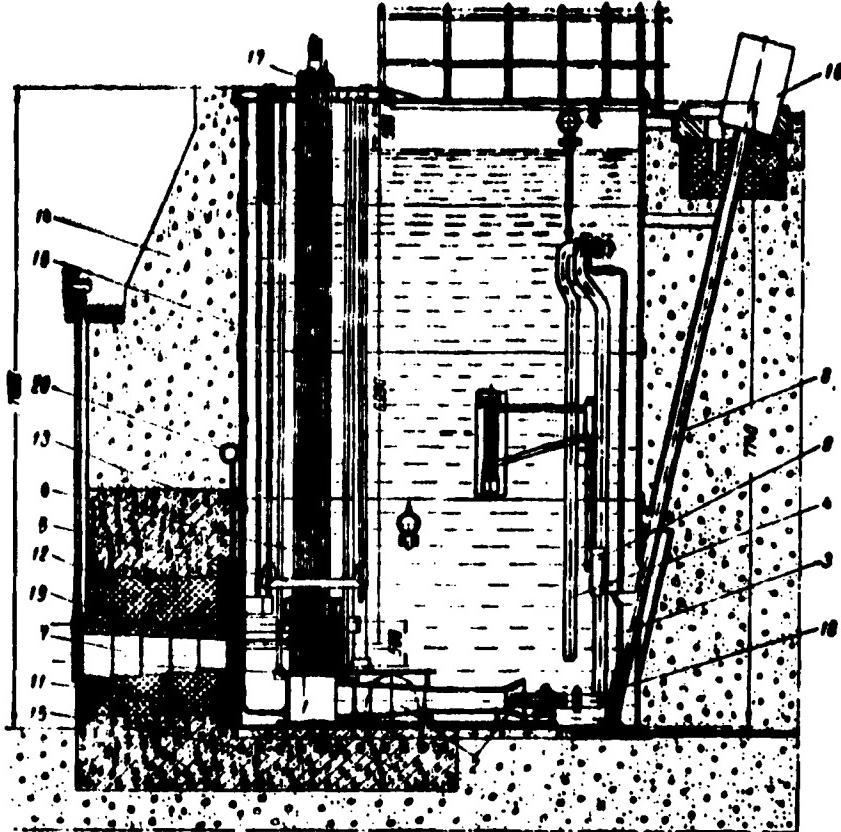
Fig. 3. Vertical cross section of the reactor [1]

1 - core; 2 - ejector tube and nozzle; 3 - cooling
water pressure line; 4 - cooling water suction line;
5 - baffle; 6 - control rod channels; 7 - beam tube
plug; 8 - tube for removal of radioactive samples
and spent fuel elements; 9 - rotating cantilever for
handling samples inside tank; 10 - container for
transporting radioactive samples and elements; 11 -
heat shielding with density of 6.5 t/m^3; 12 - shield-
ing with density of 5.1 t/m^3; 13 - shielding with
density of 4.4 t/m^3; 14 - ordinary concrete; 15 -
cooling coils embedded in the shielding; 16 - alumi-
num tank; 17 - upper platform; 18 - container for
removing radioactive samples and elements; 19 - axis
of beam tube VII; 20 - beam tube ventilation
duct header.

- 5 -
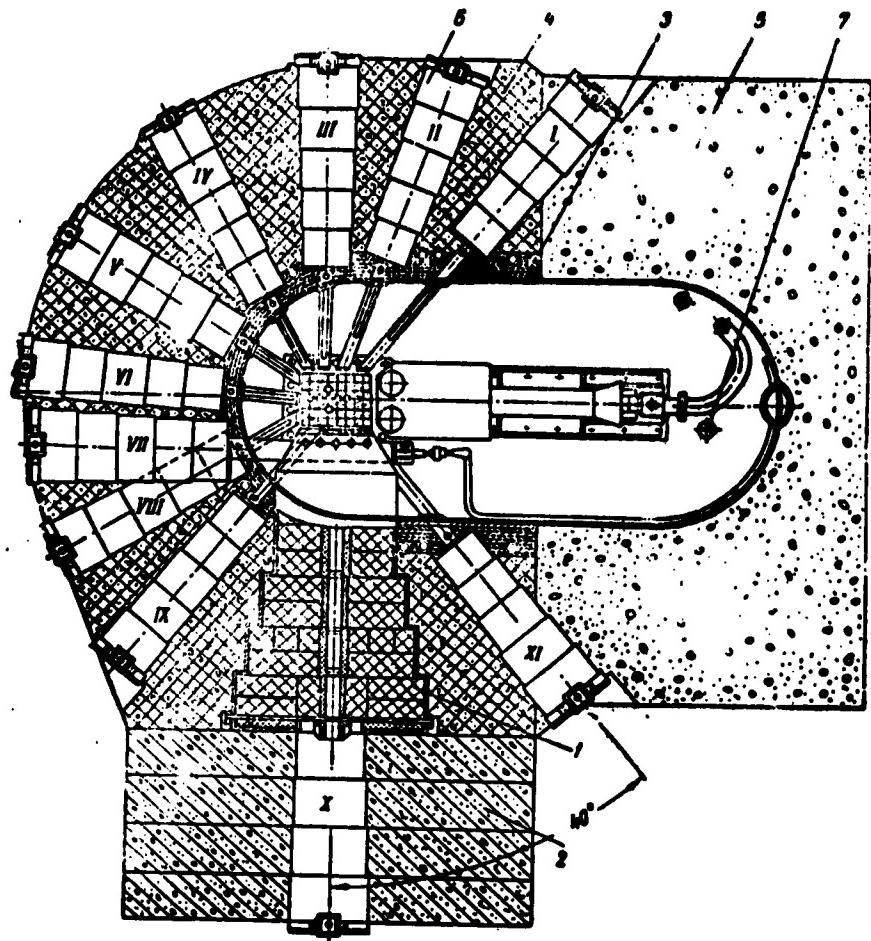
Fig. 4. Horizontal cross section of the reactor [1]

1 - thermal column; 2 - sectional shielding for thermal
column with density of 4.4 t/m³; 3 - heat shielding with
density of 6.5 g/cm³; 4 - shielding with density of
5.1 g/cm³; 5 - ordinary concrete; 6 - plug for the
150-mm diameter beam tube; 7 - tank drain; I-XI - beam
tubes.
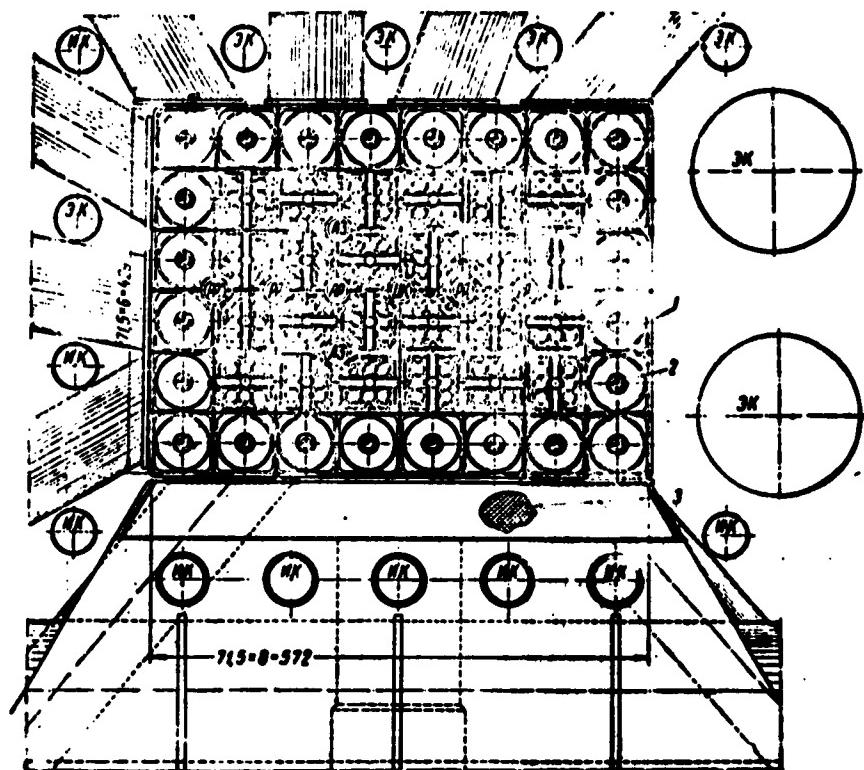
Fig. 5. Horizontal cross section of the core [1]

AP - automatic control rod; PP_1 and PP_2 - manual control
rods; A3 - safety rods; ЦК - central experimental chan-
nel 23 mm in diameter; ЭК - beam tubes; ИК - ionization
chamber channels. 1 - assembly with fuel elements; 2 -
graphite load in empty cell; 3 - lead shield.

The ejector decreased electric power consumption considerably below the level required by a cooling loop operated by centrifugal pumps alone. The pressure head of 0.9 m developed by the ejector produces a flow velocity of 2.1 m/sec, which was found to be fully adequate for heat removal. Use of the ejector also effected considerable savings in the consumption of piping material. [1]

In order to reduce radioactivity above the surface of the water, a baffle was installed to increase the flow time from the core to the surface of the tank to about 1 minute (see Fig. 3). [1]

Heat from the primary loop is transferred to the water circulating in the secondary loop by means of two tubular heat exchangers (Fig. 6). The water in the primary loop is purified in ion exchangers. Water circulates in the secondary loop at the rate of 130 m³/hr, which is adequate for reactor power levels up to 2500 kw. [1]

The reactor has the following maximal thermal parameters [1]:

Heat flux at surface of fuel elements	$4.8 \cdot 10^5$ kcal/m²·hr
Surface temperature of the fuel element	90°C
Temperature of distilled water in the tank	40°C

Since the core is located under 6 m of water, the maximum fuel element surface temperature remains 23°C below the boiling point of water. [1]

Heat released in the graphite of the thermal column is transferred to the water of the primary cooling loop, which not only circulates around the outer surface of the thermal column housing, but also flows through the annular space between the thermal column and the outer surface of the tube surrounding beam tube VII (see Fig. 4). [1]

The biological shield has its own cooling circuit, consisting of carbon steel tubes embedded in the cement. [1]

Biological Shielding

The biological shielding is composed of an iron-cement combination. A mixture of 70% alumina cement and 30% $CaSO_4 \cdot 2H_2O$ was chosen as containing the maximum possible quantity of chemically bound water. A side heat shield, 0.2 m thick, consists of a cement mixture with a density of 6.5 g/cm^3 combined with sheet steel 20 mm thick. The sheet steel amounts to almost 80% of the total volume (1.2 m^3) of the shield. Behind the heat shield, which is provided with cooling coils, there is another, more important layer of shielding made of reinforced concrete with a density of 5.1 g/cm^3. This second layer of shielding, 1.6 m thick and 1.5 m high, contains steel bar reinforcement amounting to 55% of its total volume (18.4 m^3). Each cubic meter of this shielding contains about 190 kg of chemically bound water. The top and bottom heat shields, composed of a mixture with a density of 4.4 g/cm^3, contain about 50% pig iron. Details and arrangement of the biological shield and the side, top, and bottom heat shields are shown in Figs. 3 and 4. [1]

Radiation intensities directly behind the side shielding at a power level of 2000 kw are as follows [1]:

Gamma radiation	0.016 μr/sec
Neutron flux (all energies)	3 n/cm^2·sec
Fast neutron flux (E > 1 Mev)	~1 n/cm^2·sec
Slow neutron flux (energy below the cadmium boundary)	~0.8 n/cm^2·sec

3. Reactor Control

The control rods consist of aluminum tubes filled with boron carbide brick with a density of 1.65 g/cm^3. Separate drives are provided for the automatic control rod and the two safety rods. The four manual control rods are operated by two drives. To extend the neutron flux measuring range, two ionization chambers with coarse and fine compensation are used. One of these, with a background current compensation of 10^{-5}, is for use at low power levels; the other is for high radiation intensities. An Sb-Be photoneutron source with an average intensity of 10^7 n/sec was installed in the core to raise the power of the subcritical reactor. The compensating capacity of the control and safety rods, for the initial load of 24 fuel cells, is shown in Table 1. The compensating capacity of rods decreases as the fuel load increases. [1]

Table 1. Compensating capacity of control and safety rods [1]

Rod	Compensating capacity, $\Delta k \cdot 10^{-2}$
Automatic control rod (AP)	1.95
Manual control rod PP_1	1.18
Manual control rod PP_1'	0.45
Manual control rod PP_2	1.95
Manual control rod PP_2'	1.18
Two safety rods (A3)	3.30

4. Reactor Physics

The minimum critical mass was experimentally determined for the following conditions: the vertical channels 190 mm in diameter were removed; all the horizontal beam tubes 100 mm in diameter were filled with aluminum cans containing water; both of the beam tubes 150 mm in diameter and all empty fuel cells were filled with graphite. The minimum critical mass was determined under these conditions to be equal to 2.47 kg U^{235}, a little less than the uranium content of 20 fuel assemblies. Under the same conditions but without the graphite (i.e., using water as the reflector) the critical mass was determined to be 3.17 kg U^{235}, which corresponds to the uranium content of 25 fuel assemblies. At startup, the reactor is loaded with 3.3 kg U^{235} (26 fuel assemblies) to maintain the excess reactivity ($\Delta k = 3.16 \cdot 10^{-2}$) required to compensate reactor poisoning. Toward the end of the run all 48 assemblies will be loaded. According to calculations the average fuel burnup will be 20%; the final load will be equal to 4.9 kg U^{235}, and the duration of the run (based on continuous operation at an average power level of 2000 kw) will be 1.2 years. Experiments showed that the beam tubes 100 mm in diameter shorten the reactor run very slightly, by only 2%. [1]

The thermal power of the reactor increases with the load in such a manner that the maximum thermal neutron flux remains almost unchanged. The thermal neutron flux for a load

of 24 fuel assemblies (arranged as shown in Figs. 5 and 8) was measured by the activation of sodium and by the absolute computation of induced activity. The results are shown in Fig. 7. The experiments showed that at a thermal power of 1700 kw and a neutron gas temperature of 400°C, the maximum thermal neutron flux amounts to $3.2 \cdot 10^{13}$ n/cm^2·sec. [1]

N/N max
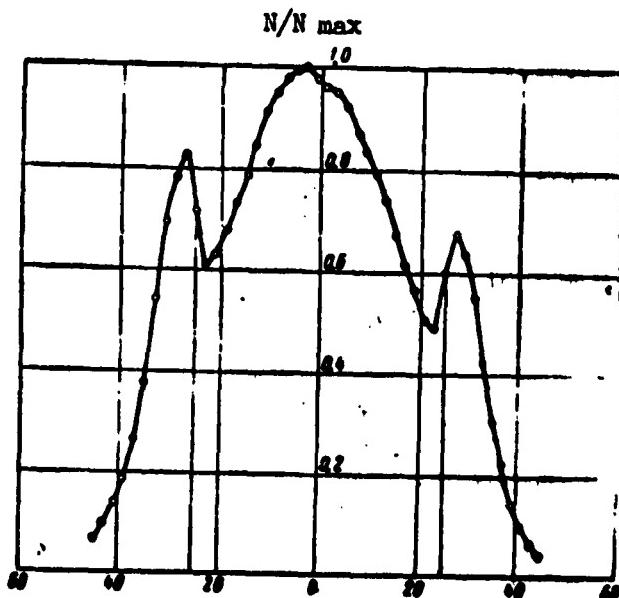
Fig. 7. Distribution of neutron densities along the height of fuel assemblies 5--5 [1]

The maximum thermal neutron flux in the fuel elements of each assembly were determined for the same conditions (Fig. 8). A volume coefficient $K_v = 2$, characterizing the nonuniformity of the neutron field in the reactor as measured by the activation of copper wires, was used in the calculations. An axial nonuniformity coefficient $K_z = 1.33$, and a radial nonuniformity coefficient $K_r = 1.5$, were determined from the same set of measurements. [1]
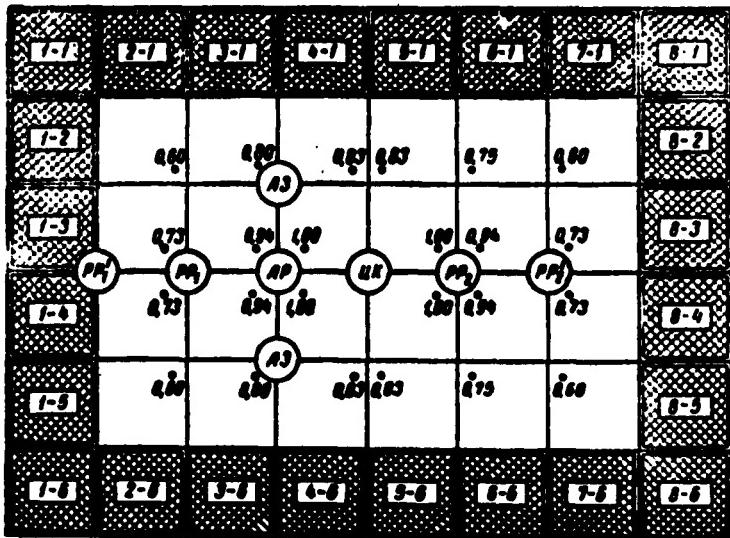
Fig. 8. Maximum thermal neutron flux in the fuel elements of each assembly [1]

(numbers in each loaded fuel cell indicate the neutron flux of the most active fuel element in that assembly; the small circles indicate the position of the most active fuel element in the assembly).

The neutron flux at the exit from the horizontal beam tubes 100 mm in diameter is shown in Table 2 [next page].

Variations in reactor reactivity during normal operations are shown in Fig. 9. The maximum reactivity loss Δk amounted to $3.6 \cdot 10^{-2}$, of which $1.2 \cdot 10^{-2}$ belongs to the "iodine pit". During operations with infrequent shutdowns, the maximum reactivity loss due to poisoning is $\Delta k = 2.85 \cdot 10^{-2}$ and the iodine pit has a "depth" of $1.25 \cdot 10^{-2}$. [1]

Variations in the thermal neutron flux and in the cadmium ratio along the length of the thermal column are shown in Fig. 10. [1]

- 13 -

Table 2. Neutron flux at exits of horizontal beam
tubes (for cadmium ratio R_{Cd} = 34) [1]

| Channel No.	Intensity of resonance neutron flux for lethargy interval	Intensity of neutron flux with energies below cadmium boundary
I	$0.5 \cdot 10^8$ n/cm²·sec	$1.0 \cdot 10^9$ n/cm²·sec
II	$0.77 \cdot 10^8$ n/cm²·sec	$1.5 \cdot 10^9$ n/cm²·sec
III	$1.0 \cdot 10^8$ n/cm²·sec	$2.0 \cdot 10^9$ n/cm²·sec
IV	$0.7 \cdot 10^8$ n/cm²·sec	$1.4 \cdot 10^9$ n/cm²·sec
V	$0.77 \cdot 10^8$ n/cm²·sec	$1.5 \cdot 10^9$ n/cm²·sec
VI	$1.1 \cdot 10^8$ n/cm²·sec	$2.2 \cdot 10^9$ n/cm²·sec
VIII	$0.77 \cdot 10^8$ n/cm²·sec	$1.5 \cdot 10^9$ n/cm²·sec
IX	$0.63 \cdot 10^8$ n/cm²·sec	$1.3 \cdot 10^9$ n/cm²·sec
XI	$0.5 \cdot 10^8$ n/cm²·sec	$1.0 \cdot 10^9$ n/cm²·sec
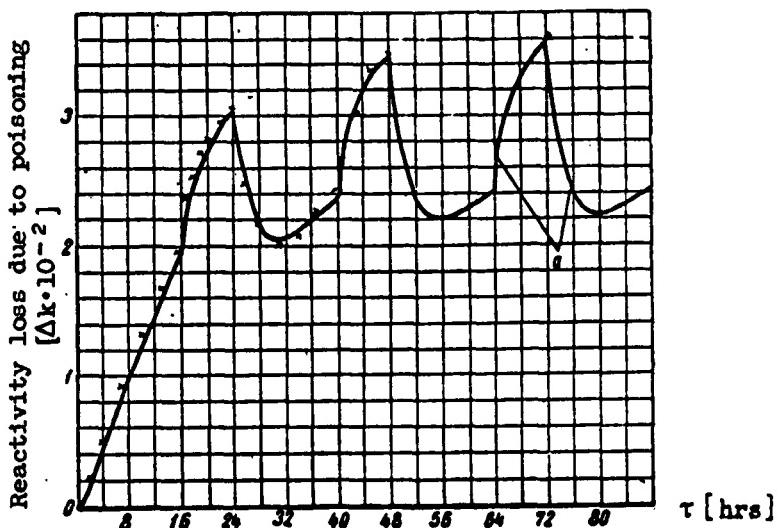
Fig. 9. Variations in reactor reactivity
during normal operations [1]

a - daily variation in reactivity (neutron
gas temperature, 400°K; Xe^{135} cross section
taken equal to $2.5 \cdot 10^6$ barn).

- 14 -
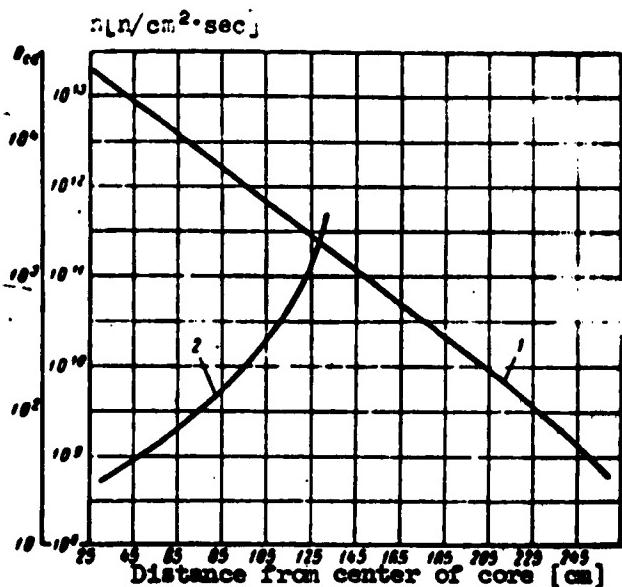
Fig. 10. Variations in the thermal neutron flux and the cadmium ratio along the length of the thermal column [1]

(neutron flux at exit of thermal column plug equals $3.3 \cdot 10^7$ n/cm$^2 \cdot$sec for cadmium ratio of 4000).

Table 3 (next page) shows experimental results concerning the effect of the beam tubes on the reactivity obtained for a load of 24 fuel assemblies (Fig. 5).

5. Experimental Facilities

The reactor is equipped with a thermal column, nine horizontal beam tubes 100 mm in diameter, and two horizontal beam tubes 150 mm in diameter (Figs. 3, 4, and 5). The shortest beam tube has a length of 2.3 m. Beam tube VII, which is intended for gamma-ray spectroscopy, is shielded from the core by a lead plate 55 mm thick. Beam tube X, located along the axis of the thermal column, is filled with graphite plugs during thermal neutron experiments. A vertical channel 23 mm in diameter, located in the center of the core, permits the maxi-

mum neutron flux in the reactor to be utilized. There are
also two vertical channels 190 mm in diameter and five verti-
cal channels 52 mm in diameter located in the reflector. [1]

Table 3. Changes in reactivity [1]

Conditions	$\Delta k \cdot 10^{-4}$
Maximum effect of a single horizontal channel 100 mm in diameter	-5
Total effect of nine horizontal beam tubes 100 mm in diameter	-22
Effect of the 150-mm beam tube located along the axis of the thermal column	-11
Effect of the 150-mm beam tube arranged perpendicular to the axis of the thermal column	-13
Increased reactivity from a single fuel assembly	+80
Increased reactivity from one graphite plug	+40

In order to minimize the escape of radioactive argon
through the ventilating tube, thin-walled, hollow aluminum
plugs were placed in the beam tubes, and the vertical chan-
nels and thermal column were hermetically sealed. [1]

Each beam tube can be closed off with a five-section
beam-tube plug, either manually or electrically actuated.
The design of the beam-tube plug is shown in Fig. 11. The
section nearest the core is made of steel and concrete, and
the other four of steel and paraffin wax containing 5% boron
carbide by volume.

[Text resumes on p. 18.]
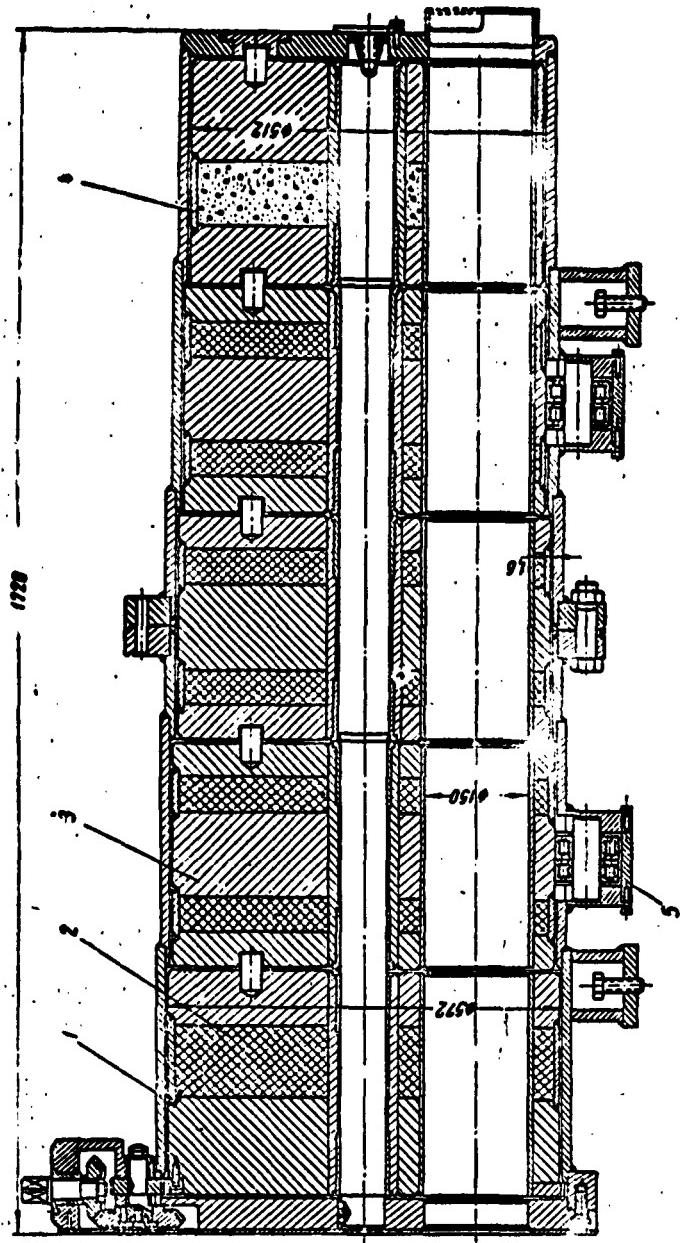
Fig. 11. Longitudinal cross section of beam tube plug for 150-mm experimental beam tube [1]

1 - body of plug; 2 - paraffin and boron carbide filler; 3 - rotating steel disk; 4 - concrete filler; 5 - supporting bearing.

6. Experimental Capabilities and Experiments Conducted With the Moscow IRT-2000 Reactor

A partial list of experimental studies which may be carried out with the reactor is given below [1]:

In nuclear physics:

Measurement of neutron cross sections
Gamma-ray spectroscopy
Neutron diffraction experiments
Experiments with polarized neutron beams
Studies of the moderating properties of
  various mixtures

In molecular physics:

Studies of the effect of radiation on solids
Molecular neutronoscopy
Structural neutronography

In radiochemistry:

Radioactivation analysis
Studies of the effect of radiation on
  chemical reactions
Radiochemistry of organic compounds

In biology:

Radiation genetics
Comparative analysis of the biological effects
  of neutron and gamma-irradiation

Some of these studies are currently being carried out [source published in 1959. --Ed.], among them the measurement of neutron cross sections by crystal spectrometer and mechanical monochromator, studies on structural neutronography and radiation genetics, and others. [1]

The Moscow IRT-2000 Reactor has also been used to investigate the corrosion of metals in experiments reported by A. V. Byalobzheskiy and V. D. Val'kov [reference 10]. The behavior of Zr--Al, Zr--Fe, and Fe--Al galvanic couples in a 0.05 N solution of NaCl under a thermal neutron flux of ~ $2 \cdot 10^{12}$ n/cm^2·sec was studied. [10]

The reactor can also be used for the production of radio-isotopes. These are prepared by irradiating chemical compounds in aluminum containers 30 mm in diameter and 102 mm long, with walls 1 mm thick. One assembly consists of 16 such containers. Up to three fuel assembly cells can be loaded simultaneously with isotope production assemblies. Yearly production of the reactor for various isotopes (assuming the entire capacity of the reactor to be devoted to the production of the isotope in question) is as follows [1]:

Na^{24} 10^4 cu/yr

S^{35} 10^4 cu/yr

P^{32} $6 \cdot 10^4$ cu/yr

Co^{60} 10^4 cu/yr

The following maximum specific activities are obtainable [1]:

Na^{24} 7 cu/g

P^{32} 2 cu/g

Co^{60} 3 cu/g

Au^{198} 100 cu/g

II. THE SALASPILS IRT-2000 REACTOR

1. General Construction

Figure 12 shows a vertical cross section of the Salaspils IRT-2000 Reactor. The following features [11] of this reactor represent departures from the design of the Moscow reactor described above:

The oval tank is 2 m in width and 4.5 m long. The core, which contains 664 fuel elements 50 cm long and 1 cm in diameter mounted in fuel assemblies, is surrounded by a beryllium oxide and graphite reflector. The distilled water coolant circulates through the core at the rate of 400 m³/hr; 300 m³/hr is circulated by the ejector, and the remaining 100 m³/hr by the centrifugal pump. [11]

Fig. 12. Vertical cross section of the Salaspils reactor [11]

1 - upper platform; 2 - cover; 3 - container; 4 - unloading chute; 5 - cooling water suction line; 6 - cooling water pressure line; 7 - vertical channels; 8 - core; 9 - ejector; 10 - concrete shielding; 11 - neutron beam.

2. Experimental Facilities

The reactor has 9 horizontal beam tubes with a cross section area of 80 cm² and a neutron flux of $5 \cdot 10^8$ n/cm²·sec. In addition, there are seven vertical channels for producing radioactive isotopes and irradiating specimens; six of these channels pass through the reflector, and the seventh through the reactor core. The neutron flux in the seventh (central) channel is $1.2 \cdot 10^{13}$ n/cm²·sec. [11] There is also a special channel for biological and chemical studies, equipped with filters to absorb thermal neutrons and to create a zone with predominantly fast neutrons

[3], and a gallium-indium loop for gamma-radiation studies [12].

Horizontal beam tube IX contains a device designed by K. Shvarts, which for the first time permits the study of changes of ion crystal spectra as a function of irradiation time. [12]

The Salaspils reactor is intended for neutron spectroscopy, and for neutron and solid state physics, including studies of the effect of radiation on materials, the chemistry of fission products, chemical reactions with radioactive isotopes, and the effect on chemical reactions of neutron and gamma-radiation. The radioactive materials produced will also be used in studies of the wear of moving machine parts. Considerable attention will also be given to biology and medicine. [11]

The following institutes will participate in research conducted with the Salaspils reactor: the Institute of Physics (headed by I. Kirko), Academy of Sciences Latvian SSR; the Riga Polytechnic Institute; the Latvian State University; the Academy of Agricultural Sciences Latvian SSR; and scientific research institutes belonging to the Department of Agriculture Latvian SSR. [11]

3. Experiments Conducted With the Salaspils Reactor

The reactor is operated and research work is conducted under the supervision of the Institute of Physics, Academy of Sciences Latvian SSR [11]. Some of the investigations conducted with the Salaspils reactor in the research facilities of the Institute are described below:

E. Trinkler studied the effect of gamma-radiation on the magnetic permeability of ferrites at -195°C; he found that ferrites irradiated with 1000 r/sec exhibit a sharp decrease of initial permeability [12; 13]. I. Plyavin studied optical processes in alkali-halogen crystals [12]. I. Feltynya studied diffusion processes in crystals [12]. G. Upita studied surface phenomena in solids and succeeded in producing surfaces of superhigh purity containing no atoms or molecules of other substances. In the course of his investigations he discovered the "self-polishing" effect, in which molecules and atoms of a solid body distribute themselves over the surface to approach a state of minimum free energy [12]. Nuclear physicists L. Pelenkis, O. Veveris, and Kh. Gunne developed a method of using radioactive krypton to test the hermetization of instruments [12].

The reactor has an electromagnetic transporter which delivers radioactive specimens from the reactor to the laboratory in a matter of seconds. The activation of chemical reactions can thus be studied with isotopes having half-lives of the order of minutes and even seconds. [12]

V. Breslav developed a device for measuring the lifetimes of atomic nuclei of the order of 10^{-16} sec [12]. P. Prokof'yev constructed an improved beta-spectrograph and an apparatus for polarized neutrons [12]. U. Ul'manis used modern methods to measure the neutron flux distribution in the reactor [12].

The Institute of Physics is also engaged in studies in magnetohydrodynamics and plasma physics. Riga is considered a special center for magnetohydrodynamic studies, and, next to Moscow, employs the largest group of scientists in this field. [12]

Theoreticians at the Institute of Physics study the fundamental processes of plasma formation by atomic collision. Veldre, Damburg, and Peterkop developed processes which will be used in the first Soviet power plant equipped with magnetohydrodynamic generators. [12]

The Central Technical Design Office has developed electromagnetic pumps for magnesium and other nonferrous metals. [12]

Many laboratories will be built in Salaspils in the next few years. The laboratory for magnetohydrodynamics will use sodium flowing at high Reynolds numbers for studying various magnetohydrodynamic problems, including some relevant to space exploration. [12]

III. THE TBILISI IRT-2000 REACTOR

1. General Design

The general design of the reactor is similar to that of the Moscow IRT-2000 Reactor. No general views or cross section diagrams of this reactor are available.

2. Reactor Control

The reactor control system consists of eight ionization chambers, two safety rods, four manual control rods, and one automatic control rod. [14]

3. Experimental Facilities

The reactor is provided with 10 horizontal beam tubes and 12 vertical experimental channels. One of the vertical channels, 23 mm in diameter, passes through the center of the core; nine vertical channels 52 mm in diameter and two vertical channels 190 mm in diameter are located around the periphery of the core. [14]

In addition, the reactor is equipped with a Ga-In alloy loop to extend its research capability in high-intensity gamma-radiation fields. The principal flow diagram of this loop, which generates a gamma field of 10^4 to 10^5 g Ra, is given in Fig. 13. It consists of the following components: 1) an alloy activity generator in the form of a plate let into the core in an experimental channel; the alloy circulating through perforations in the plate is activated by neutron irradiation; 2) a stainless steel cylinder for gamma-irradiation; 3) an electromagnetic pump; and 4) a magnetic flowmeter. The design and construction of the loop was carried out by the Physics Institute, Academy of Sciences Georgian SSR, the Atomic Energy Institute, Academy of Sciences USSR, and the Physics Institute, Academy of Sciences Latvian SSR. One of the basic purposes of the loop was to investigate the effect of irradiation on the corrosion properties of 1X18H9T [AISI-321] steel, specimens of which were exposed to a total neutron dose of 0.5 to $0.7 \cdot 10^{18}$ n/cm^2. [15]

The reactor is also equipped with various special devices, such as a neutronograph and a neutron polarizer. Two new laboratories, a radiochemistry laboratory and a laboratory for producing short-lived isotopes, are under construction at the reactor site. [16]
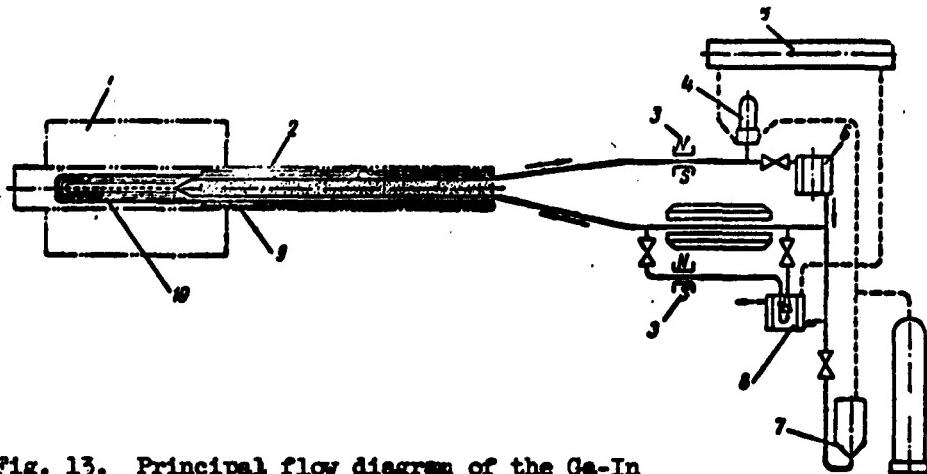

Fig. 13. Principal flow diagram of the Ga-In loop of the Tbilisi reactor [13]

1 - reactor core; 2 - boron carbide plug; 3 - flowmeter; 4 - level gage; 5 - volume compensator; 6 - gamma-radiation source; 7 - overflow container; 8 - filter; 9 - channel tangent to reactor core; 10 - activity generator; solid line - alloy circulation line; dotted line - argon circulation line.

4. Experiments Conducted With the Tbilisi Reactor

Some of the investigations conducted with the Tbilisi reactor are described below: E. L. Andronikashvili, N. G. Politov, and L. F. Vorozheykina investigated the effect of lattice disturbances on the mechanical and optical properties of KCl crystals [17]. Andronikashvili, Politov, and S. Sh. Getiya also investigated the effect of irradiation on the structure and hardness of alkali-halide crystals, exposing the specimens in one of the vertical channels of the reactor to a neutron flux of $1.03 \cdot 10^{12}$ n/cm^2·sec [16]. In addition, some 50 research studies have been conducted "over the last three years" [source published in Nov 1962. --Ed.] in the fields of polymorphism of metals at low temperatures, radiation cracking of hydrocarbons, nuclear structure, and others [18].

IV. THE TOMSK IRT-2000 REACTOR

The Tomsk IRT-2000 Reactor is still under construction. When completed, it will be the first research reactor in Siberia. According to reference [19] the reactor was expected to be completed in 1962. No details are available at this time.

V. THE SVERDLOVSK IRT-2000 REACTOR

The Sverdlovsk IRT-2000 Reactor [1], belonging to the Ural Branch, Academy of Sciences USSR, was stated to be under construction in 1958 [8]. No further information could be found at this time.

VI. THE MALYYE DUBNY IRT-2000 REACTOR

1. General Design

The following design features [9] of the Malyye Dubny IRT-2000 Reactor represent departures from the design of the original Moscow reactor: 1) A cooling loop with an outlet from the reactor into the reactor hall was hooked up to the central vertical channel [9]. 2) A second hot chamber, to accomodate specimens with an activity of 1000 cu, was built into the concrete of the biological shielding; it is equipped with a lead glass window for visual observation and a manipulator for handling specimens [9]. 3) A part of the operating and control equipment was moved from the reactor room to permit the installation of scientific laboratories [9]. 4) Improved control and safety systems were installed [9]. 5) Core and horizontal beam tubes were modified to adapt them for experimental purposes [9].

2. Experimental Facilities

The experimental facilities of the Malyye Dubny reactor include eight horizontal beam tubes 10 mm in diameter and two horizontal beam tubes 150 mm in diameter, nine vertical channels ranging from 50 to 180 mm in diameter, and one central channel 23 mm in diameter [9].

The reactor is also provided with an experimental heat transfer loop for experiments with organic coolants, especially polyphenyls [19]. The principal flow diagram of this experimental loop is shown in Fig. 14, while Fig. 15 shows how the parts of the organic loop are located in the reactor. In the core the loop was accommodated by replacing the four fuel assemblies surrounding the central channel with specially designed assemblies which form a cylindrical duct 60 mm in diameter (see Fig. 16, page 30). Seven standard fuel elements, encased in a steel tube of 40 mm inner diameter, are placed in the center of the duct. This tube is encased in another steel tube of 50 mm inner diameter. The heat exchange assembly is enclosed in a tube 1.5 m high and 60 mm in diameter, which forms an annular clearance 2 mm wide between the heat exchange section and the reactor pool. Direction of coolant flow is from bottom to top inside the fuel assembly and from top to bottom in the annulus. The annulus can be evacuated to provide thermal insulation. Using standard fuel elements, a heat flux of $0.5 \cdot 10^6$ kcal/m^2·hr can be obtained. The seven
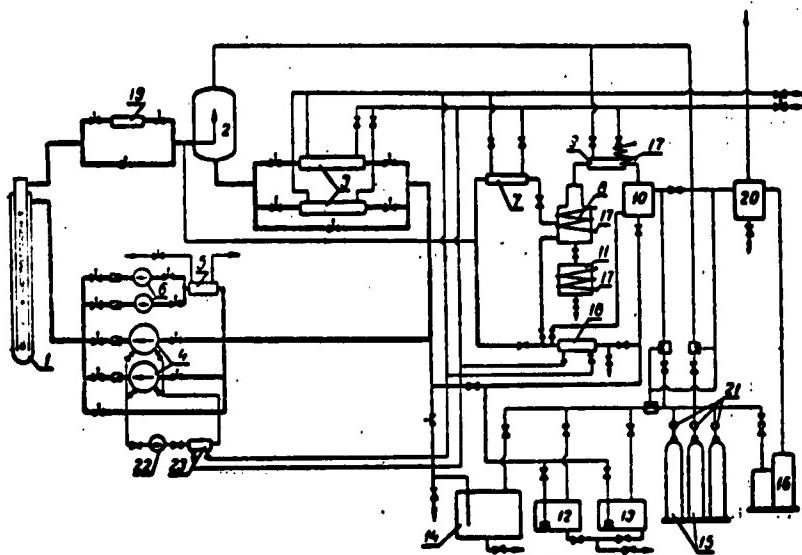
Fig. 14. Principal flow diagram of the experimental organic heat transfer loop of the Malyye Dubny reactor [19]

1 - fuel assembly; 2 - separator-compensator; 3 - main heat exchanger; 4 - circulating pump; 5 - emergency cooler; 6 - emergency pumps; 7 - purifier cooler; 8 - purifier-vaporizer; 9 - purifier condenser; 10 - condensate collector; 11 - small drainage tank; 12 - makeup tank; 13 - clean drainage tank; 14 - contaminated drainage tank; 15 - compressed nitrogen tanks; 16 - vacuum pump; 17 - electric heater; 18 - sampling cooler; 19 - experimental section of loop; 20 - gas separator; 21 - gas pressure regulators; 22 - cooling pump; 23 - secondary cooling for main pump bearings.

elements have a total thermal power of 128 kw. Coolant at 400°C is discharged from the heat transfer section at the rate of 25 m³/hr. Calculations made by the Atomic Energy Institute, Academy of Sciences USSR, showed that operation of the loop will decrease reactor activity by only 1% (Fig. 17). The loop includes sections for separating gaseous and polymerized fractions and for compensating the loss of the withdrawn gaseous products with nitrogen, drainage facilities, sampling ports, pumps, and two heat exchangers for transferring heat from the coolant to water. [19]

[Text resumes on p. 30.]
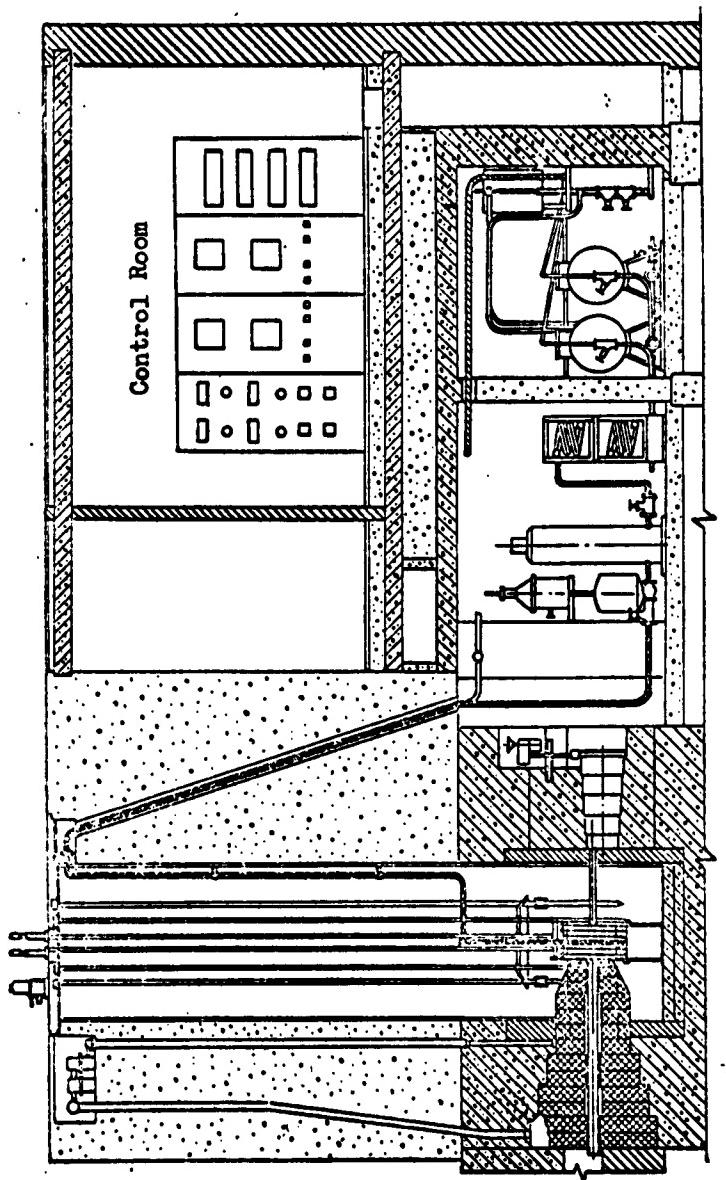
Fig. 15. Cross section of the reactor, showing location of components of the experimental organic loop [9]

Control Room
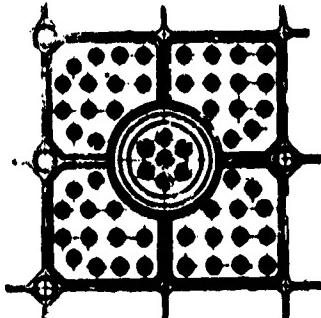
Fig. 16. Loop channel in
the core of the Malyye
Dubny reactor [19]
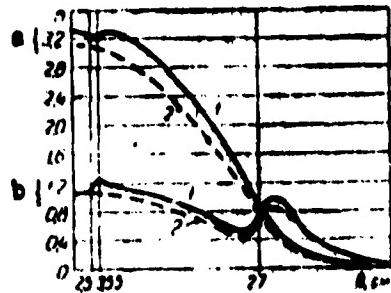
Fig. 17. Distribution of fast
and thermal neutrons along the
radius of the core with and
without organic loop
(for 20% U^{235} burnup) [19]

a - fast neutrons; b - thermal
neutrons; 1 - with loop; 2 -
without loop.

3. Research To Be Conducted With the Loop

The experimental heat transfer loop described above will
make possible studies such as those described below:

1) Decomposition of various coolants under irradiation and
high temperatures, with reference to: a) the dependence of the
rate of coolant decomposition on temperature, radiation dose,
irradiation time, and type of coolant used; b) composition
and quantities of decomposition products (gases and nonvolatile
residue); and c) optimum operating temperatures for organic
coolants [19].

2) Heat transfer between fuel elements and coolant, to
include: a) determination of the mean heat transfer coeffici-
ent along a fuel element; b) determination of design relation-
ships; c) determination of optimum heat transfer for various
coolant types and compositions and for various fuel element
designs; and d) heat transfer in a boiling organic fluid [19].

3) Tests of various fuel element designs to obtain fuel
element design data for reactors using organic coolants [19].

4) Corrosive action of organic coolants in contact with
various structural materials to determine the feasibility of
using ordinary unalloyed steels and other materials in reac-
tors with organic coolants [19].

5) Effect of the loop on the values of the effective multiplication factor and the neutron distribution ratio in a reactor [19].

6) Study of the performance of various reactor control systems and devices [19].

7) Tests to obtain biological shielding design data for primary circuits using organic coolants [19].

Preliminary experiments in the loop have been conducted with monoisopropyldiphenyl [19].

Research using this reactor will be conducted by the Physics Institute, the Institute for Physical-Organic Chemistry, the Biology Institute, the Physiology Institute, the Department of Solid State Physics and Semiconductors, and the Agricultural Institute, all of the Academy of Sciences Belorussian SSR; the Department of Nuclear Physics, Belorussian State University imeni V. I. Lenin, will also participate in the research. [9].

REFERENCES

1. Goncharov, V. V., Yu. G. Nikolayev, Ye. N. Babulevich, and Yu. F. Chernilin. Experimental pool-type 2000-kw reactor (IRT). IN: International Conference on the Peaceful Uses of Atomic Energy. 2d, Geneva, 1958. Trudy konferentsii. Yadernyye reaktory i yadernaya energetika (Transactions of the conference. Nuclear reactors and nuclear energy). Moskva, Atomizdat, 1959. 273-293.   QC770.I53 1958

2. Bulkin, Yu. M., and Ye. N. Volkov. Nuclear reactor for research purposes. Inzhenerno-fizicheskiy zhurnal, v. 1, no. 10, Oct 1958, 3-10.   TA4.I83, v. 1

3. Kokis, P. The atomic reactor of the Academy of Sciences Latvian SSR becomes operational. IN: Latvijas Padomju Socialistiskas Republikas Zinatnu Akademija. Vestis (Izvestiya), no. 10(171), 1961, 122-126. [in Russian]
                AS262.R6 1961

4. News briefs [2d item]. Atomnaya energiya, v. 9, no. 2, Aug 1960, 158.   QC770.A83, v. 9

5. From all parts of the country ['news briefs]. Pravda, 21 Jul 1962, 4, col. 4.

6. Tsitsishvili, G. The electron stream is in motion. Zarya vostoka, 21 Nov 1959, 2, cols. 4-5.

7. News briefs [1st item]. Atomnaya energiya, v. 12, no. 5, May 1962, 443.   QC770.A83, v. 12

8. News briefs [3d item]. Atomnaya energiya, v. 4, no. 4, Apr 1958, 401.   QC770.A83, v. 4

9. Yermakov, V. S. Start-up of the first Belorussian nuclear reactor. Inzhenerno-fizicheskiy zhurnal, v. 5, no. 8, Aug 1962, 138-139.   TA4.I83, v. 5

10. Byalobzheskiy, A. V., and V. D. Val'kov. Investigation of the corrosion of metals in the experimental channel of an IRT reactor. Atomnaya energiya, v. 10, no. 5, May 1961, 525-528.   QC770.A83, v. 10

11. News of science and technology. Latvian research reactor [unsigned article]. Atomnaya energiya, v. 7, no. 1, Jul 1959, 79-80.   QC770.A83, v. 7

12. Kirko, I. On the frontier of science. Sovetskaya Latviya, 20 Dec 1962, 2, cols. 5-7.

13. Trinkler, E. I. The effect of gamma-radiation on the magnetic permeability of a number of ferrites. IN: Konobeyevskiy, S. T. (ed.). Deystviye yadernykh izlucheniy na materialy [sbornik] (Effect of nuclear radiation on materials [collection of articles]). Moskva, Izd-vo AN SSSR, 1962. 370-373.

14. Chernilin, Yu., and V. Gomelauri. Happy birthday to you, our peaceful atom. Zarya vostoka, 20 Nov 1959, 2.

15. Andronikashvili, E. L., B. G. Buda, G. I. Kiknadze, L. I. Fel'dman, and V. M. Chanturiya. Model of the indium-gallium alloy radiation loop [designed] for the Tbilisi IRT-2000 reactor. Atomnaya energiya, v. 13, no. 4, Oct 1962, 342-349. QC770.A83, v. 13

16. Andronikashvili, E. L., N. G. Politov, and M. Sh. Getiya. Effect of irradiation in a reactor on the structure and hardness of alkali-halide crystals. IN: Konobeyevskiy, S. T. (ed.). Deystviye yadernykh izlucheniy na materialy [sbornik] (Effect of nuclear radiation on materials [collection of articles]). Moskva, Izd-vo AN SSSR, 1962. 277-287.

17. Andronikashvili, E. L., N. G. Politov, and I. F. Vorozheykina. Effect of lattice disturbances on mechanical and optical properties of potassium chloride crystals. IN: Konobeyevskiy, S. T. (ed.). Deystviye yadernykh izlucheniy na materialy [sbornik] (Effect of nuclear radiation on materials [collection of articles]). Moskva, Izd-vo AN SSSR, 1962. 268-276.

18. Tsilosani, L. The atom in the service of peace. Zarya vostoka, 6 Nov 1962, 3, cols. 2-4.

19. Yermakov, V. S., and V. A. Sokol'chik. Experimental organic loop of the IRT-2000 reactor of the Academy of Sciences Belorussian SSR. Inzhenerno-fizicheskiy zhurnal, v. 4, no. 12, Dec 1961, 109-117. TA4.I83, v. 4